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Polyvinyl acetate adhesives for wood

A large range of synthetic polymers is produced from vinyl acetate monomer; the largest part of this production is used in making polyvinyl acetate (PVAC) adhesives and in a variety of surface coatings. The use of PVAC glues has grown steadily since they began to replace animal glues for bonding timber. They are versatile 'general purpose' adhesives which can be formulated to glue a wide variety of surfaces, including materials such as PVC and expanded polystyrene that are difficult to bond to porous substrates such as timber and wood-based sheet materials.

PVAC adhesives are available in which the polymer is dissolved in a suitable organic solvent but, for wood adhesives, dispersions of the solid polymer in water are usually used. These are loosely referred to as 'emulsions' or 'white glues'.

One-part glues

One-part PVAC wood glues are widely used in furniture and cabinet making, in general assembly gluing and for finger jointing of timber for non-structural uses.

The thermoplastic one-part PVAC glues are unsuitable for structural bonding of wood, or where the joint is exposed to moisture, high humidity or high temperature. Their suitability for use on wood joinery exposed to severe weather is also in doubt because any impairment of the glue bond caused by ingress of moisture at the joints may be exacerbated by the consequent movement tending to occur between the timber components.

Because of the thermoplastic and elastic nature of the glue line, the strength of PVAC glued joints is extremely sensitive to the duration of loading and to the geometry of the joint.

When tested to failure with single overlap joints loaded in tensile shear, commercial PVAC glues usually show joint strengths in excess of those of the thermosetting wood glues. Early failure due to stress concentrations in the glue line does not occur because the elasticity of the PVAC glue line allows stresses to be distributed over a larger area of the joint. However, when PVAC joints are continuously stressed using dead loads as low as one-third of those causing immediate joint failure, plastic deformation and eventual failure of the joints occurs.

Under sustained load, the time to failure decreases markedly as the temperature, the relative humidity or the moisture content of the timber adherends are increased. For example, increasing the relative humidity from 60 to 65 per cent may reduce the time to failure by 50 per cent,

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whilst an increase in temperature from 20° to 25°C has been found to reduce the mean time to failure from 130 hours to 30 hours for a set of ten samples under load. Immersion of joints in cold water for 24 hours generally results in virtually complete loss of bond strength.

PVAC emulsion glues are non-toxic and non-flammable, allow easy cleaning of manufacturing equipment after use and yield colourless glue lines which are claimed to cause less wear on cutting tools than most other adhesives.

Since no catalyst is required, no mixing is necessary before use and the time during which the glue is usable (the 'pot-life') is usually in excess of 24 hours. They require lower glue spread than urea formaldehyde (UF) adhesives and are less likely to cause problems on assembly lines because of setting of the glue in the distribution lines to automatic equipment.

The bond is formed by the diffusion and evaporation of water from the glue line. This 'cure' process may be accelerated by increasing the temperature but it should not exceed 70°C or blistering in the glue line may result because of the thermoplastic character of the glue. Similarly, in assembly gluing, temperatures above 70°C may cause the joints to spring apart unless they are clamped until cool.

Two-part catalysed glues

The limitations of one-part glues stimulated the development of modified PVAC adhesives having improved moisture resistance while retaining the advantages of long pot life and rapid cure. Blending PVAC with urea formaldehyde or resorcinol-formaldehyde resins yielded some improvement in performance, but the use of a catalyst to produce a cross-linked polymer structure was found to give optimum performance with convenience in use.

Tests on a range of two-part PVAC adhesives under various simulated conditions have shown that close-contact joints (in which the glue line thickness was less than 0.1 mm), made and tested under standard conditions, can have bond strengths similar to those achieved by one-part glues. Like one-part PVAC glues, they are not formulated as gap-filling glues and gap joints (with glue line thickness of 1.25 mm) were found to have up to half the strength of close contact joints.

Two-part systems have better moisture resistance and whilst they may lose between 50 and 85 per cent of their original bond strength after immersion in cold water for 48 hours, this loss is usually recovered after drying. There is no significant loss of bond strength at low temperatures. Full exposure to natural weathering may eventually result in some loss of strength but efficient bonds are usually maintained; indeed, tests have sometimes shown a small increase in joint strength, particularly on redwood samples. When glued joints are fabricated without applying heat, the progressive cure can continue for many months at ambient temperature, especially in winter.

The limitations of the catalysed PVAC glues become apparent when they are subjected to sustained loads. Few can meet the requirements of BS 4071 that the specimen joints must resist the specified load for not less than seven days in dry conditions, suggesting that the chemical cross-linking reaction is not completed during the seven days of conditioning prior to testing. In humid conditions, failure often occurs within 24 hours (the rates of failure with conventional PVAC glues are generally even more rapid). Their resistance to sustained loads does, however, increase considerably in outdoor winter conditions; the low

ambient temperatures prevailing during the winter months slow the rate at which the glues, which are evidently thermoplastic to some degree, tend to creep.

From experience of two-part PVAC adhesives, particularly in Germany and other European countries, it is considered that the best of these glues have adequate moisture resistance for use in external joinery and may be used in conditions of severe exposure to weather, but only for non-structural joints.

Durability and predictive testing

In assessing the resistance of individual glues or classes of adhesive to weather and to degradative factors, it is clear that prolonged natural exposure testing is the most reliable guide. However, the methods of classification for phenolic and aminoplastic resin adhesives, which rely on a number of simple laboratory tests, have enabled rapid and reliable assessment of new glues within this category, without the need to await the results of this prolonged testing. Recent German (DIN) Standards have proposed using one of these tests, a six-hour boil test, as a means of predicting the durability of *any* non-structural wood glue, and of determining its suitability for use in situations where exposure to moisture will occur.

Since some two-part catalysed PVAC glues, unlike the conventional types, will meet the minimum strength requirements of the DIN Standard boil test as well as the requirements of BS 1204 for the WBP ('Weather and Boil Proof') classification, it is sometimes stated that catalysed PVAC's can produce glue lines equivalent to those of, for example, resorcinol-formaldehyde glues of WBP type. This is true only in that the joints of both will survive boiling. There is no correlation between the strength of joints after boiling and the durability of PVAC glues when exposed to weather and other moisture hazards.

An analysis of the experimental data for two-part PVAC joints exposed to weather and to various conditions in the laboratory showed that the strength of beech slip joints immersed in cold water for 48 hours and then re-dried to normal wood moisture content (about 12 per cent) could be used to correlate the data for a number of the tests performed with exposure to weather.

In summary, it was found that where the mean failing load of the water-soaked BS 1204 samples after drying was not less than 4 kN when tested in longitudinal shear, glued joints showed good retention of bond strength after 12 months exposure to weather (this applied to gap and close contact joints, both fully exposed and in an open-sided shed). In addition, these materials also performed well in the sustained load tests out of doors.

The cold-water test therefore shows promise as a predictive test to identify catalysed PVAC glues suitable for use in applications such as external joinery for exposed conditions. Its validity will need to be further tested by experience of these glues in service.

Wood at high moisture contents and treated with preservatives and water repellents

An increasing amount of non-durable timber which has been treated with preservatives against wood-destroying fungi is now used for exterior joinery in building. Since this material may be used for the fabrication of glued joints it is essential that the adhesive used is compatible with the preservative.

Timber is usually glued at a moisture content between 12 and 15 per cent, when experience indicates that optimum bond quality will be obtained, and this is stipulated in BS 4169 and CP 112. However, drying to the desired moisture content is a costly process and, particularly for applications where higher timber moisture contents are likely to persist in service, it would be advantageous to glue the timber at higher moisture contents.

One and two-part PVAC emulsions have been tested[1] to determine the influence of moisture content at the time of gluing. Glue bonds were made between redwood and whitewood timber at equilibrium moisture contents of 12, 20 and 26 per cent; some of these were tested after storage at these conditions for five weeks while others were conditioned to 12 per cent moisture content before testing. The one-part glue was found to be clearly unsuitable for gluing timber at moisture contents higher than 12 per cent, since highly significant strength losses occurred at both 20 and 26 per cent. In accordance with experience of natural weathering, the two-part glue was able to give good bonds when tested at 12 per cent, even though the joints had been fabricated at 20 or 26 per cent moisture content. However, when tested at 26 per cent moisture content the glue was completely unsatisfactory. Information is also available on the effects of gluing whitewood timber with various preservative treatments (some with different amounts of paraffin wax water repellent), using one-part and catalysed PVAC glues[1]. Although the results show that both PVAC glues are generally compatible with the preservatives examined, it is notable that only the one-part adhesive gave satisfactory performance when the highest amount of wax (one per cent) was present. However, this glue is not suitable for bonding timber exposed to moisture, and in view of the strength loss and failure predominantly in the glue line observed with the catalysed glue, it is clearly advisable that timber with such high contents of wax should be bonded with appropriate adhesives such as RF and RF/PF formulations, which give satisfactory bonds.

Reference and further reading

1 The effect of moisture content and wood preservatives on the assembly gluing of timber; RH Laidlaw and BH Paxton; BRE Current Paper CP 54/74
The performance of some catalysed polyvinyl acetate wood adhesives; JC Beech; Journal of the Institute of Wood Science; Vol 7, No 6 (issue 42); Winter 1977

British Standards
BS 1203: 1963 Synthetic resin adhesives (phenolic and aminoplastic) for plywood
BS 1204 Synthetic resin adhesives (phenolic and aminoplastic) for wood
Part 1: 1964 Gap-filling adhesives
Part 2: 1965 Close-contact adhesives
BS 3544:1962 Methods of test for polyvinyl acetate adhesives for wood
BS 4071:1966 Polyvinyl acetate (PVA) emulsion adhesives for wood
BS 4169:1970 Glued-laminated timber structural members
CP 112 The structural use of timber

German Standards
DIN 68602 (Dec 1973) Glued wood joints: stress groups
DIN 68603 (Feb 1974) Glued wood joints: testing

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